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UNITED NATIONS EDUCATIONAL,
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MEETING OF EXPERTS ON THE USE OF SPACE COMMUNICATION BY THE MASS MEDIA
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BROADCAST SATELLITE POSSIBILITIES(1)

by

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(1) The author has submitted this paper for consideration by the meeting and assumes responsibility for the views expressed in it.

1. The discussion of the general subject of using artificial earth orbiting satellites as broadcast stations is an intriguing one, and is by no means new. In fact, it was the mission envisioned by Arthur C. Clark in his original paper on extra-terrestrial relays which appeared in the literature in 1945. Since then, the subject has been widely discussed by many authors. While the concept of direct broadcasting is now 20 years old, it is only recently that space technology has developed to a point where it is practicable to consider the development of such satellites within the foreseeable future.

2. A purpose of this paper is to discuss the technical possibilities for providing radio and television services via satellites to conventional home receivers and to specially designed receivers which might be used for specific information distribution systems which may be applicable to the requirements of the educational services with which this meeting is primarily concerned.

(ILLUSTRATION 1)

3. The first thing to do is define broadcast satellite. By direct broadcast, we mean that an earth station transmitter would transmit program material to a satellite, which would amplify the received signal and retransmit it direct to individual home radio or television receivers. Satellites from which the program material is received by more elaborate receiving equipment than the current commercially available home receivers are called distribution satellites. Just to complete the definitions, we refer to the current communication satellites - which require reception by very complex ground equipment from which program material must be subsequently delivered to the consumer via wire or rebroadcast, by conventional local transmitters - as point-to-point satellites.

4. In discussing the various possibilities, television broadcasting will be discussed first because it is what most people think about. Voice broadcast satellites will be discussed later. We normally and quite naturally would prefer being able to receive television program material on receivers comparable to our existing home television receivers. Not only on our existing receivers, but we would also like to receive with simple antennas or at least no more than listeners are now generally accustomed to use with their receivers. A direct broadcast satellite will have to radiate a great deal of power so that the signals it retransmits to home receivers will be strong enough to be picked up by such a conventional receiver antenna installation.

5. There have been a great range of estimates of the kind of power such a service requires; and I will try to explain why this is. Basically there are two reasons; the acceptability of a television picture containing various levels of noise or interference or distortion is a highly subjective quantity. The quality of picture required of a particular service, in addition to being a subjective consideration, is truly a variable. Certainly the quality of picture required to convey elementary instruction can be considerably different from that required to convey the intricacies of medical surgery, for example. Picture quality as I shall show is extremely expensive.

(ILLUSTRATION 2)

6. To illustrate this point, we show here a categorization of quality of service related to signal to noise ratios developed by the Television Allocation Study Organization[1] (TASO).

Of the six grades of service shown, you seldom get Grade 1 service or "excellent" picture quality. Usually Grade 2 classified "fine" service is the kind of service usually realized in urban areas. It is considered by many listeners to be more than necessary. Grade 3 or the "passable" service for rural areas may be acceptable for many applications. Note the wide differences in the signal to noise required among the various grades. The decibel is a logarithmic scale so that every 3 decibels is a doubling of the power requirements.

(ILLUSTRATION 3)

7. Class I service cannot be provided to current grade home receivers, without an outdoor antenna, even with the largest space power supplies now being considered. A 35 kilowatt nuclear reactor is the largest one currently under development. Grade 2 service can be provided for an area of approximately 1 million square miles if we assume a reasonable sized antenna of the "fring-area" type on rooftops looking up at the satellite. The nuclear reactor or equivalent solar power capability, and Saturn-sized boosters would have to be used to place such a capability in space. If the receiver and antenna is augmented with a good preamplifier stage, the space power required to provide the same grade of service can be reduced by a factor of 3. It should be further noted that the technology for required large space erectable antennas and the capability to point it to selected land masses is also required and these technologies although rapidly being developed have not been demonstrated to date.

8. This brings me to the second reason for the wide range of estimates of power and satellite size required for television broadcasting, and that is the degree to which one departs from the conventional receiver and increases the costs of the receiver installation. It will be pointed out that the degree of difficulty of the space segment is largely dependent on the character and sophistication of ground equipment used for receiving transmissions from a broadcast satellite. In view of the recent tremendous technological progress in receiver components, it became desirable that these advances be considered in our deliberations on space telecasting. We are now making a comparative analysis of the cost of various combinations of ground receiving equipment that we might relate to satellite effective radiated power and size.

(ILLUSTRATION 4)

9. On the screen is our current crude estimate of this relationship. (As mentioned we are at this time attempting to refine these costs). The area on the left refers to large expensive ground terminals capable of receiving from low powered satellites of the RELAY and SYNCOM class. The performance of any

(1) TASO is an organization established by the U.S. television industry for the purpose of conducting a study of "the technical principles which should be applied in television channel allocation", in response to the Federal Communications Commission's request which was issued on 31 August 1956 in Public Notice 35638.

communication system is basically limited by the amount of noise present. RELAY, TELSTAR and the Communication Satellite Corporation's "Early Bird" satellite derive relatively small amounts of power from solar cells and batteries and the spacecraft antennas provide relatively low gain. This means that the effective radiated power from such satellites is quite low - in the order of tens of watts. As a result, the signals transmitted from these satellites are very weak by the time they reach the earth, and as a consequence large, expensive ground terminals are required to pick up the signals. The right hand areas represents the costs of conventional home receivers which could only be used in conjunction with megawatt range satellites. The center area illustrates that between the two extremes there is a large area for compromise where ground receivers of reasonable complexity could be made to work.

10. We feel that the results of comparative analysis of receiver costs will provide the kind of information we need to permit optimum spacecraft size-to-ground receiver trade-offs to be made for each particular application.

11. There are a number of interesting approaches to space television broadcasting. The ones which offers the earliest possibility of development are in the distribution satellite area.

12. As I have indicated there is a broad area of technical possibilities if an increase in complexity and cost of the ground TV receiver is allowed. For example, if one would permit the design of a new receiver, making use of frequency modulation techniques instead of amplitude modulation techniques, and permit the use of an antenna connected to the receiver - then the following could be done.

Reduce the size and weight of the spacecraft thereby permitting the use of proven lower cost launch vehicle combinations

Reduce the complexity of the spacecraft thereby making possible the use of technology which has either been flight proven or which is already in an advanced state of development.

Substantially reduce the amount of space power required, and provide higher quality reception.

Reduce the development time required for establishing an operational capability by as much as a factor of 2.

(ILLUSTRATION 5)

13. For example, one spacecraft design concept would be basically an outgrowth of our current Application Technology Satellites (ATS) which utilizes an expanded cylindrical solar cell array to increase available solar power with minimal weight increase. In May of this year, Hughes Aircraft submitted a proposal to us for such a distribution satellite concept.

14. An artist's conception of this satellite is shown on the screen, with SYNCOM III and our Applications Technology Satellite, ATS-B alongside for size comparison. The spacecraft design is basically an ATS which utilizes an expanded cylindrical solar cell array, 9 foot diameter x 6 foot tall, to increase the available power, without

weight increase. The spacecraft weighs the same as current ATS spacecraft - 1,550 pounds, and would utilize the same launch vehicle and kick motor to place it into a geostationary orbit. The required rf power would be obtained by driving each of the sixteen elements of the antenna with a separate traveling wave tube amplifier.

15. In this approach, all of the major spacecraft sub-systems are either identical with or derived from ATS, and no major technological breakthroughs or long-term developments are required for its accomplishment.

16. With 10 kilowatts of effective radiated power from the satellite, use of frequency modulation on the down link, and a low noise preamplifier, it is possible to use a 6 foot receiving antenna attached to the receiver.

(ILLUSTRATION 6)

17. Another spacecraft design concept which would use the same size ground receiver would utilize a large pointable antenna. This approach would minimize the electronic complexity of the spacecraft considerably, but would entail the development of large aperture antenna techniques for space. For example, the same amount of effective radiated power could be achieved, but using a single 10 watt transmitter aplifier tube instead of the sixteen traveling wave tube amplifiers needed in the first design concept. The tradeoffs in terms of cost and reliability of these plus other approaches must be studied in detail before choices can be made as to which type of spacecraft is optimum.

18. In the related field of direct radio broadcast, NASA has been examining the technical aspects of such satellites. We have recently requested the U.S. industry to submit proposals for a study of the feasibility of satellites capable of broadcasting directly to conventional home FM radios and/or shortwave radios. At the outset, we were only giving consideration to a FM broadcast satellite because of the difficulty and vagaries of transmitting through the ionosphere.

(ILLUSTRATION 7)

19. Two sets of conditions are shown on the screen. On the left, are the earth coverage patterns for transmission through the ionosphere under normal conditions. The patterns apply to the frequencies noted on lines delineating coverage on earth. On the right, the coverage is much reduced due to the poor quality of the transmission media. However, since this characteristic deserves more study, we have included shortwave broadcasting in our feasibility studies.

20. The space power required for voice broadcasting is substantially less than that needed for direct TV. Approximately 3 to 5 kilowatts of prime power would be required to provide sufficiently strong signals, on a clear channel basis, for reception by conventional radios equipped with currently available outdoor antennas.

(ILLUSTRATION 8)

21. When considering space broadcast systems, one must determine which are the optimum orbits for such satellites. There are a variety of possible orbits for these satellite systems, but the desirability of relatively simple receiving

antennas for home reception, and of uninterrupted broadcasting at the most desirable listening or viewing times, just about preclude serious consideration of all but stationary satellites using the synchronous orbit, 22,300 miles above the earth. Lower than synchronous orbit satellites would not only require complex receiving antennas on the roof which would have to be capable of tracking different satellites, but the satellite ground transmitters would be more complex as well. Also, the number of low altitude satellites that would be needed to insure uninterrupted broadcasting would probably make the cost of such a system prohibitive or if only a few were used, the availability of service would be less than 100% of the time.

22. More than a third of the surface of the earth would be visible from a single stationary satellite. This would permit the use of fixed antennas at home receivers, and at earth stations used to transmit programs to the broadcast satellite over wide geographic areas.

23. Another factor associated with space telecasting from the synchronous orbit is that signal fading usually attributed to motion through antenna lobes or to multipath propagation is essentially eliminated. The relatively high angle of arrival and uniformity of signal strength for the space system, over most of the coverage area, greatly reduces the allowances for signal degradation in conventional broadcasting systems due to factors such as reflection or terrain absorption and man-made noise.

(ILLUSTRATION 9)

24. Inasmuch as the space power requirements are so large to broadcast directly to home receivers on a hemispheric basis, transmission to selected land masses are in order to effect a great reduction in space power. Three land masses are encircled on the screen, representing the antenna patterns from satellite in the geostationary orbit. For example, a 30 foot diameter antenna operating in UHF broadcast band would provide the coverage shown for India. A broadcast satellite in a stationary orbit could continuously point its antenna to the selected land mass to which transmissions are being sent. It is generally accepted that the aforementioned advantages of the synchronous orbit for broadcast satellites outweigh problems of providing a larger weight-lifting capability, and a higher transmitting power capability.

25. At the 10th Plenary Assembly of the CCIR, held at Geneva in February 1963, the CCIR agreed to study the feasibility of direct sound and television broadcasting from satellites, including the question of what frequency bands would be technically suitable for such broadcasting, and whether these bands could be shared with terrestrial services.

26. The Extraordinary Administrative Radio Conference (EARC) was convened in October 1963 to allocate frequencies for space use. The EARC made extensive allocations for communications satellites in bands already allocated for terrestrial point-to-point service, and established detailed criteria for the sharing of these frequencies between the terrestrial and space broadcasting, but recommended that the CCIR expedite its studies on the feasibility of broadcasting from satellites. The EARC <u>did</u> adopt a definition for the "broadcasting satellite service", from which one can infer that they expect such a service to come into being.

27. As you were well aware, terrestrial broadcasting takes place in a number of frequency bands below 1,000 mc. Broadcasting allocations above about 20 mc. are potentially suitable for space broadcasting as well. If parts of these existing allocations were to be set aside for space broadcasting on an exclusive basis, there would be no sharing problem - but if existing allocations must be shared between terrestrial and space broadcasting, then sharing criteria must be established so that neither service interferes unduly with the other. A number of detailed studies on this subject have been performed in the United States, in particular by Mr. Haviland of the General Electric Company, and some results of this work have been proposed for inclusion in CCIR reports.

28. Even though there are no international space broadcasting allocations as such, it is possible for a national administration to employ space broadcasting, under ITU regulations which provide that allocated bands can be used for other purposes provided that no harmful interference be caused to the "authorized" services. Another regulation provides that two or more members of the Union may conclude special agreements regarding sub-allocation of frequencies.

Satellites for program distribution would probably not operate in the bands allocated for direct broadcasting.

29. In considering where they might operate, frequency-wise, one might make a distinction between an educational distribution system and a commercial program distribution system.

30. For example, it might be possible for an educational system to share frequencies now used for links between a studio and its transmitting station. In general, when frequency allocations for similar terrestrial services do not already exist, the problem of finding suitable frequencies is more difficult but when they do, extrapolation to space is an appropriate consideration.

31. In summary although there are not now frequency allocations for these services, there is no reason to believe that with wise planning in the immediate future, and by recognizing that there may be a different availability of the spectrum in different geographic areas it should be possible to accommodate these services.

SUMMARY

32. Before closing, I want to give you our estimates of what will be required to transmit television and voice or aural program material from spaceborne transmitters directly to conventional home receivers in terms of space power, size and time scale. Requirements will also be given for distribution satellites plus our estimates of ground receiving equipment costs. These estimates are based on satellites in a geostationary orbit, and for direct TV and FM radio satellites a 30-foot parabolic antenna on the spacecraft is assumed. For direct TV, the area of coverage would be approximately 1 million square miles.

33. Direct TV to a conventional UHF receiver equipped with a folded dipole antenna would require a transmitter power of one megawatt in order to provide Grade 1 service. 65 kilowatts is required if a fringe area antenna is used; and 15 kilowatts if a good transistor preamplifier is added.

34. For Grade 2 service 100 kilowatts is required for a dipole antenna; 5 kilowatts if a fringe area-type antenna is used; and 1,500 watts transmitter power if a good preamplifier is added.

35. For Grade 3 service, the transmitter power just enumerated is reduced by a factor of 4.

36. A satellite capable of providing TASO Grade 1 service would require Saturn-type boosters and the time to develop the space power technology is about the one decade or more.

37. If Grade 2 service is provided, and fringe area-type antennas were used, the time scale could be cut in half.

38. Smaller launch vehicles could be used for a satellite capable of providing Grade 3 service. The time scale might be reduced somewhat if fringe area antennas were used.

39. For distribution-type TV satellites, Atlas-Agena-type launch vehicles could be used to place approximately a 1,500-pound satellite in orbit. Since such a satellite would make maximum use of today's technology, it is estimated that 3 years would be required to date of first launch. As pointed out earlier, a new receiver making use of frequency modulation techniques and a 6-foot diameter antenna would be used to provide Grade 1 service to users. Cost estimates for the receiving equipment ranges from $10,000 for quantities of 100 or slightly more to between $1,000 and $3,000 for quantities in excess of $10,000. It should be remembered that we are still in the process of conducting comparative cost analysis for various kinds of ground receiving equipments in the TV broadcast area. Therefore, you should treat these cost figures as gross estimates at this time.

40. For direct voice broadcast satellites the transmitter power requirements are of the order of 1 to 3 kilowatts. The variation in power takes into account the range of sophistication of typical home installation; namely, the wide variation of sensitivity of the receivers and different types, if any, of antennas encountered. The estimates of spacecraft weight range from 2,000 to 3,000 pounds. Currently available boosters can be used to place a voice broadcast satellite in orbit. Hemispheric coverage has been assumed for these satellites. Again, a minimum of 3 years is required to develop a satellite of this general magnitude.

41. All that has been talked about is a capability for providing a single channel, and without benefit of specific users' needs in terms of number of channels required and quality of picture. Should the user requirements be more than one channel, then the job becomes more difficult and obviously larger spacecraft would be required

than I have assumed in my estimates. On the other hand, if the picture quality requirements for educational purposes is considerably in excess of currently acceptable standards for commercial purposes, or if they can be relaxed, as we have pointed out, this would have considerable bearing on the cost, size and time required for spacecraft development.

42. It should be noted that the time scales we have talked about apply to a logical and technically sound program plan for the development of such useful capabilities in space. We recognize that it would be possible to provide merely demonstrations of television and voice broadcasting from space on perhaps an earlier time scale. But if each step is to contribute to the ultimate goal of practical availability of such capabilities, we feel that the time scales mentioned are realistic.

43. In conclusion, I would like to say that we are optimistic concerning the rate of technological development in these and related areas. In point-to-point communications satellites, in a period of less than 5 years, the required space technology for operational point-to-point communications satellites was developed. This is clearly evidenced by the Communications Satellite Corporation's Early Bird satellite. Substantial advances have been made in large boosters and in space power sources. NASA's Pegasus satellite clearly demonstrated the technical feasibility of deploying large panels for micrometeorite detection. Similar techniques might be used for deploying the large solar cell arrays required for direct broadcast satellites. While a good deal of technology remains to be demonstrated in space and there are many policy determinations which need to be made prior to the launching of any broadcasting satellite, we are very encouraged by the progress being made in technology which can be applied to broadcast satellites for any purpose.

DIRECT BROADCASTING
FROM EARTH SATELLITES

DEFINITION

PROGRAM MATERIAL IS TRANSMITTED DIRECTLY FROM THE SATELLITE TO INDIVIDUAL HOME RECEIVERS.

DIFFERENT FROM POINT-TO-POINT COMSATS

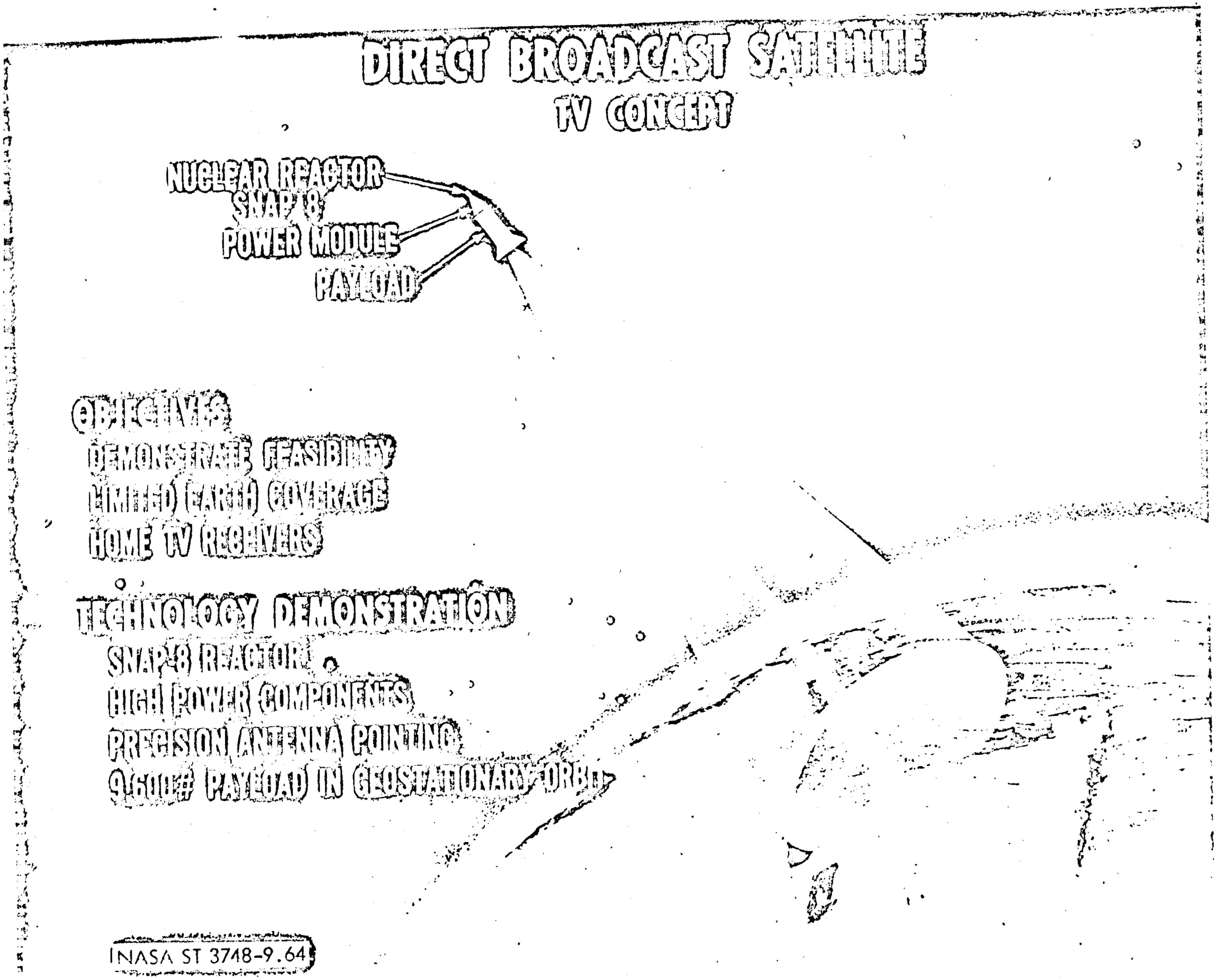
- NO ELABORATE RECEIVING EQUIPMENT REQUIRED
- NO REDISTRIBUTION TO LOCAL AUDIENCES VIA:
  - WIRE
  - RE-BROADCAST
  - OTHERWISE

TELEVISION QUALITY VS ACCEPTANCE

(FROM TASO PANEL 6 DATA)

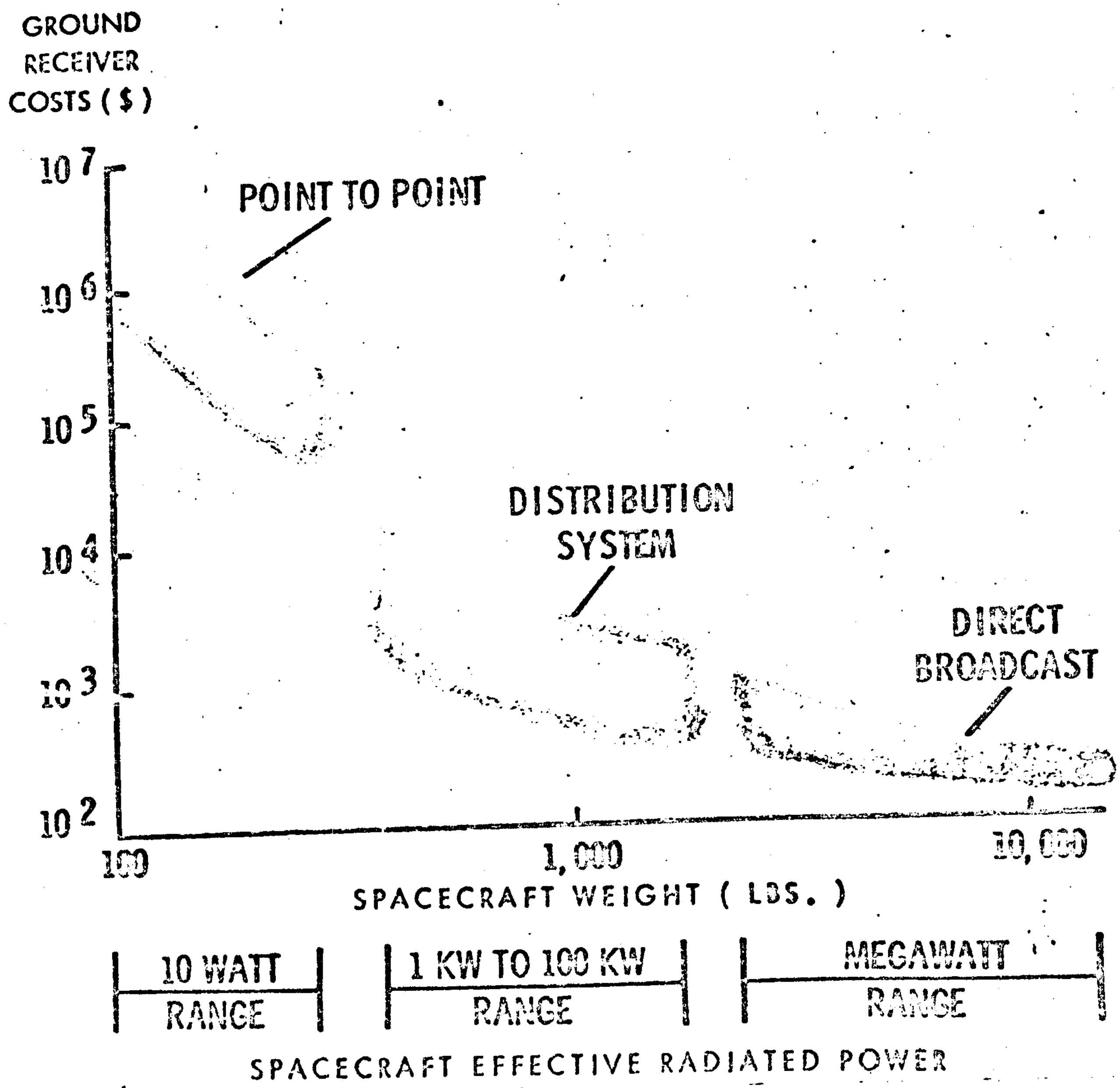
GRADE	NAME	% OF PEOPLE RATING "PASSABLE"	SIGNAL-TO-NOISE RATIO (db
1	EXCELLENT	99.9	41
2	FINE	85	33
3	PASSABLE	50	28
4	MARGINAL	15	23
5	INFERIOR	1	17
6	UNUSABLE	0	11-

(ILLUSTRATION 2)



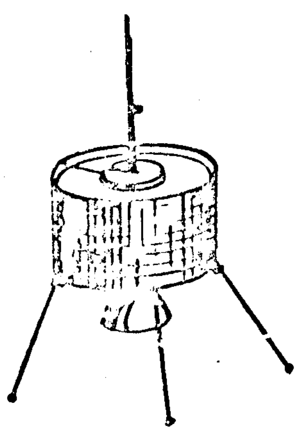
(ILLUSTRATION 3)

GROUND STATION COST
VS
SPACECRAFT WT & ERP



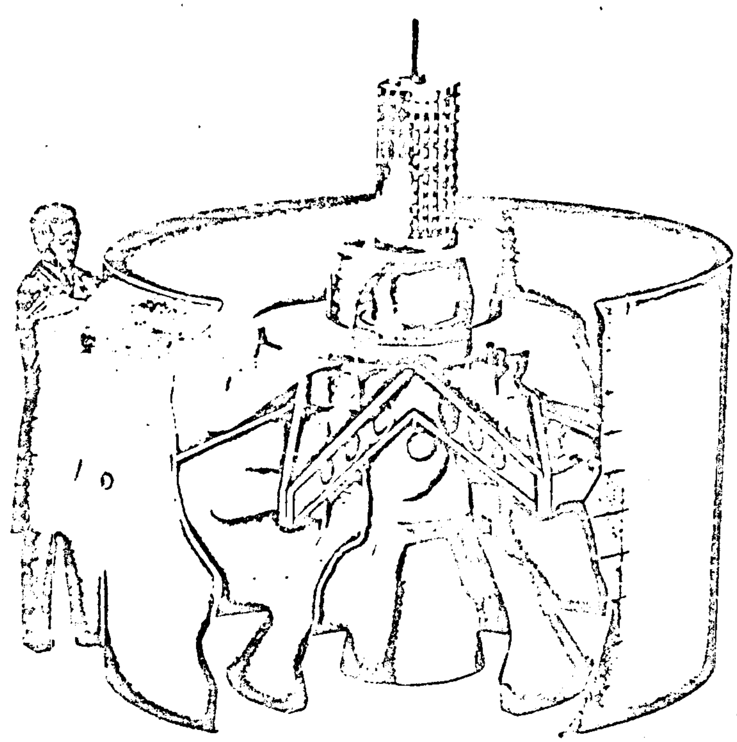
NASA ST 65-1655
10-26-65

TV DISTRIBUTION SATELLITE

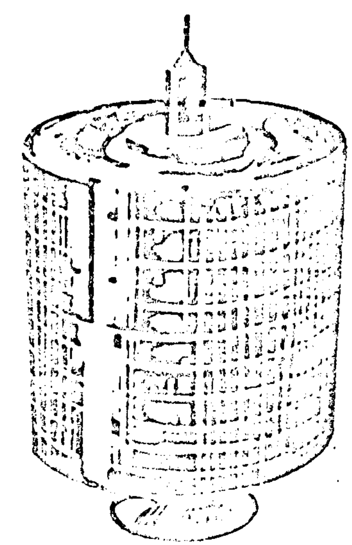


SYNCOM III

145 LBS.



1,550 LBS.
LAUNCH WEIGHT

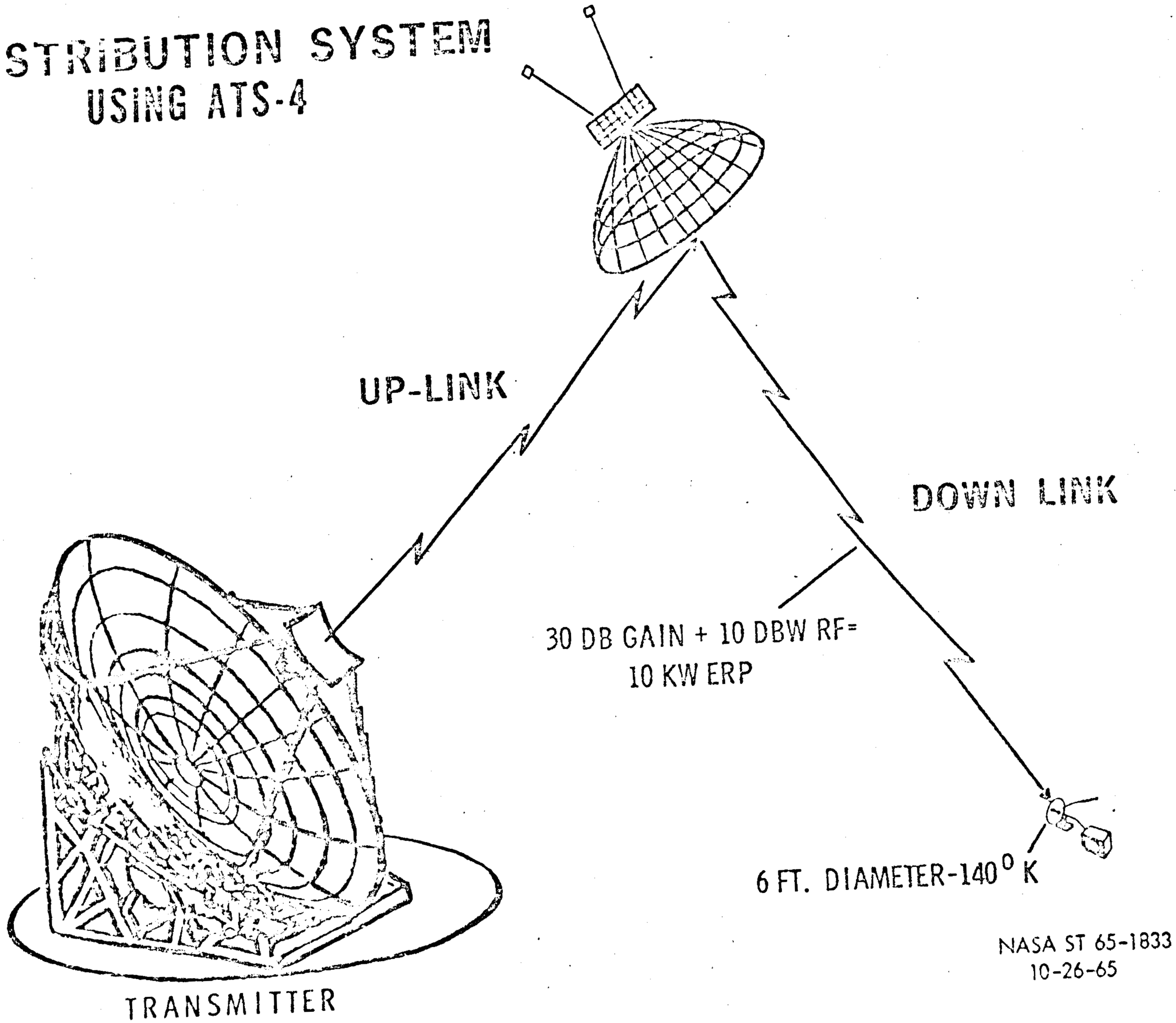


ATS-B

1,550 LBS.

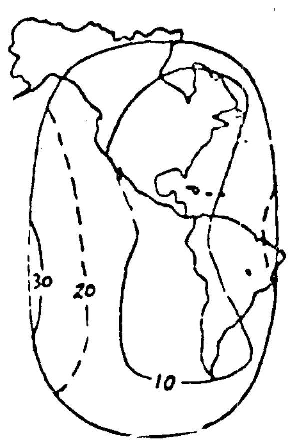
NASA ST 65-1834
10-26-65

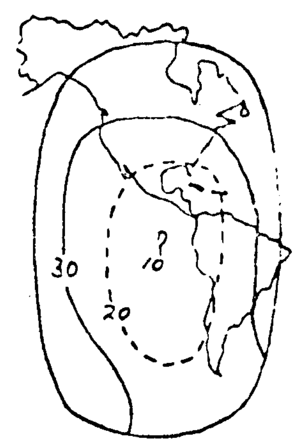
TV DISTRIBUTION SYSTEM USING ATS-4



NASA ST 65-1833
10-26-65

HF (AM) VOICE BROADCAST SATELLITE COVERAGE

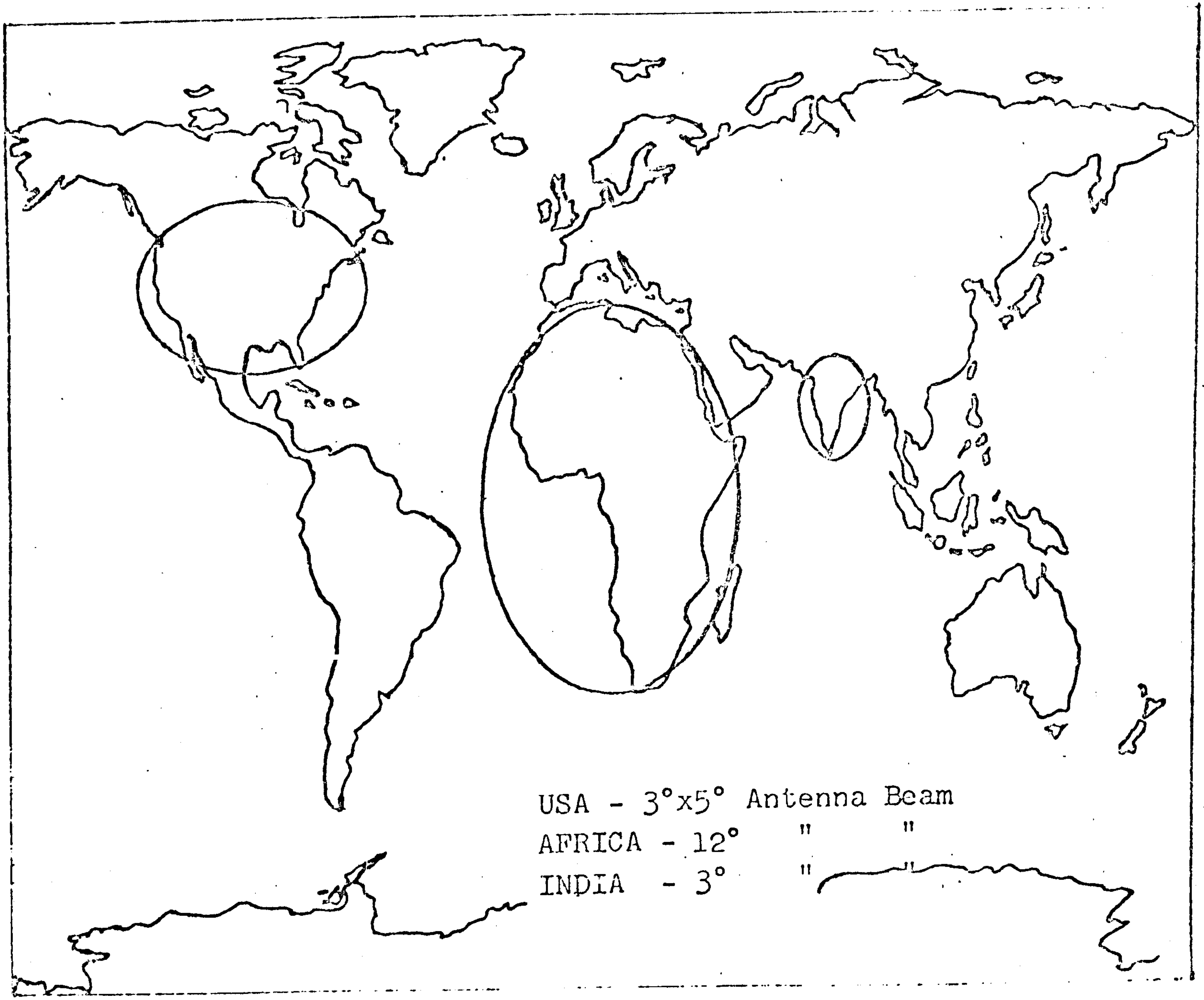




- NOTE LIMITED AREA AND VARIABILITY OF COVERAGE
- COMPONENT SIZES ARE LARGE

(ILLUSTRATION 2)

ANTENNA PATTERNS FOR SYNCHRONOUS BROADCAST SATELLITE



(ILLUSTRATION 8)

FREQUENCY AVAILABILITY

CURRENT ITU POSITION -- PERMITS EXPERIMENTATION IN ANY BANDS, INCLUDING BROADCASTING, ON PREARRANGED (RR 118) OR N-I BASIS (RR 115, 700)

-- NO EXPLICIT PROVISIONS FOR EXPERIMENTAL SPACE BROADCASTING.

-- ENCOURAGES CCIR CONTINUE STUDIES ON TECHNICAL FEASIBILITY, SHARING

BROADCASTING BANDS IN EXISTING ITU ALLOCATIONS =

HF	5.9 - 6.2 Mcb.	(49 m)		VHF	41 - 88 Mc/s	(mainly TV)
	9.5 - 9.8 Mcb.	(31 m)			88 - 108 Mc/s	(mainly FM)
	11.7 - 11.97 "	(25 m)			174 - 216 Mc/s	(TV)
	17.7 - 17.9 "	(19 m)		UHF	470 - 890 Mc/s	(TV)
	21.4 - 21.7 "	(15 m)				
	25.6 - 26.1 "	(11 m)				

- FEEL MUST HAVE EXCLUSIVE USE OF ASSIGNED CHANNELS.
- EXCLUSIVE ASSIGNMENT DOES NOT REPRESENT TOO GREAT A PROBLEM, EXCEPT IN U.S.
- FEEL POSSIBLE IN U.S. - COULD SET ASIDE OR RESERVE UHF CHANNELS BY REMOVING FROM ASSIGNMENT PLAN.